MINERALOGICAL AND GEOLOGICAL ORE TYPES OF BRAZILIAN PHOSPHATE ORES

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INTRODUCTION

Brazilian phosphate deposits are mainly of alkaline igneous origin, which distinguishes them from the most important world phosphate resources, of sedimentary origin. The deposits are characterized by their low grade and complex mineralogy, reflecting the diversified composition of apatite bearing rocks of alkaline/carbonatitic complexes. Several mineral resources have been recognized worldwide in such intrusions(4). Apatite is the most ubiquitous mineral, occurring in significant concentrations in at least 10 brazilian localities(1,2). Among the varied suites of rocks from brazilian alkaline/carbonatite complexes(3), apatite mineralization is associated mainly to carbonatites (sovites, beforsites, ferrocarbonatites), glimmerites and pyroxenites, and only locally to fenites, ijolites and syenites (Anitápolis and Ipanema).

Apatite deposits have been recognized in fresh rocks, but mainly in their overlying weathering mantles, up to more than 150 metres thick. In fact, among several deposits being exploited, only at Jacupiranga fresh carbonatites are mined. Additional potentially significant phosphate resources of sedimentary or other, not yet well-established origin, also occur in Brazil (Table 1), but are presently of limited importance, due to technological and/or economic restrictions.

TABLE 1: Brazilian phosphate deposits

ASSOCIATION		IN OPERATION	UNEXPLOITED
ALKALINE ROCKS AND CARBONATITES	WEATHERING MANTLE	ARAXÁ (MG) TAPIRA (MG) CATALÃO (GO) SERROTE (SP)	ANGICO DOS DIAS (BA) CARACOL (PI) ANITÁPOLIS (SC) IPANEMA (SP) SALITRE (MG) MAECURU (PA)
	FRESH ROCK	JACUPIRANGA (SP)	
SEDIMENTARY ROCKS		PATOS DE MINAS (MG) LAGAMAR (MG)	IGARASSU (PE) PAULISTA (PE) IRECE (BA)
OTHER			ITATAIA (CE) TRAUÍRA (MA) PIROCAUA (MA)

Although a limited market for natural-application fertilizer and thermophosphate exists, most of the brazilian phosphates are used to produce apatite concentrates for the fertilizer industry and, at Jacupiranga, also for technical and food-grade phosphoric acid production. Specifications for these concentrates are rather strict and most impurities are related to the presence of specific minerals in the phosphate ores. So, an adequate knowledge of the nature and distribution of the mienralassembly in the deposit is required, from the mienral exploration phase on an through the whole lifetime of the mine, for control of flotation plant products and mine planning purposes.

MAIN CHARACTERISTICS OF THE BRAZILIAN PHOSPHATE DEPOSITS

Most of the following considerations are based on experience acquired at deposits of alkaline/carbonatitic origin. Many may be extended to other phosphate deposits, especially the aspects related to the behavior of primary phosphate bearing rocks exposed to weathering processes.

Fluorapatite is normally considered the predominant primary phosphorus mineral of alkaline/carbonatitic complexes, while francolite or carbonate-fluorapatite is the primary mineral in sedimentary deposits. Recent detailed studies of several brazilian igneous occurrences, however, revealed that in most situations fluor-hydroxyl-(carbonate)-apatite is a more appropriate designation.

Later processes related to weathering, or sometimes of hydrothermal character, may result in recrystallization and/or reprecipitation phenomena, originating CO_3 enriched apatite varieties (fluor-carbonate-apatite). These late apatites, normally of fine prismatic character, frequently are intergrown with minute grains of dispersed iron oxides and hydroxides. They occur in the alteration profile overlying the alkaline/carbonatitic rocks as: granular multicrystalline aggregates; in compact phosphate crusts, composed of eluvial grains of the primary apatite cemented by the secondary carbonate-enriched apatite; covering the cavities walls in the hard crusts.

Rocks from alkaline/carbonatite intrusions are remarkably variable in mineral composition. Furthermore, successive and distinct geological episodes result in accentuated intermingling of different rocks. Frequently, lithological denominations simply express the local dominant variety. Thus, the silicocarbonatites represent a mixture of predominant carbonatites with silicate rocks (e.g. glimmerites). Since their apatite contents normally are rather different, grades masy change markedly over short intervals.

The complex distribution of the primary rocks is therefore responsible for the main lateral variations in igneous phosphate deposits and is also reflected in their weathering mantles. These alteration profiles show an aditional vertical zoning, more or less developed, according to the intensity and evolution of the weathering processes.

Significant mineralogical, textural and grain size variations are relatedto the vertical zoning in weathering deposits. A complete profile, not necessarily present in all deposits, may be subdivided into several layers from surface to the fresh rocks:

a Surficial red clay-rich lateritic cover and/or ferricrete;

b Non-apatitic layer, with varied contents of very fine secondary Ba, Sr, and Al phosphates, not recovered by existing froth flotation processes. The layer may be enriched in Nb, Ti, Fe, REE, Ba and Sr, sometimes in economic levels;

c Main apatite bearing earthy layer, frequently enriched in relation to the primary rocks. Carbonates have been completely removed by leaching. Ferromagnesian silicates are totally decomposed. Transformation of biotite and phlogopite into clay minerals and iron oxides occurred in the top level, but in lower portions of the layer the micaceous habit of strongly discolored minerals, as vermiculite, hydrobiotite and chlorite, is still recognized. Chemically, high Fe_2O_3 contents, MgO not higher than 2% and P_2O_5 enrichment (mainly in carbonatite rich complexes), characterize this layer. In some deposits, reprecipitation and cementation by fine grained apatite and carbonate-apatite originate hard and very rich phosphate crusts, with very fine disseminated iron oxides.

d This horizon is similar to the **c** layer, with residual preservation of the original silicates. At its basal portion, the moist material acquires a greenish tint, due to the color of the primary micas, pyroxenes and amphiboles. Sometimes residual rock structures may still be recognized at undisturbed, moist surfaces.

e Layer with little weathered silicate minerals, the preserved original rock textures and structures on undisturbed surfaces, corresponds to 'decomposed rock'; carbonates, very subordinate to absent at the top, become common minerals at the lower portion of the layer, specially when the underlying fresh rocks are of carbonatitic nature. Even some relics of serpentinized olivines may be locally preserved.

f Very slightly weathered primary rocks, except for the serpentinized olivines; pyrite and pyrrhotite are common accessory minerals.

Secondary non-apatitic phosphates, originated by the decomposition of apatite, decrease sharply from top to bottom of the alteration profile and are almost absent in the two lower layers. Figure 1 illustrates the behavior of the most important minerals in the weathering mantles overlying alkaline/carbonatitic rocks.

PHOSPHATE ORE TYPES AND TECHNOLOGICAL CONSIDERATIONS

Phosphate deposits associated to alkaline and carbonatitic rocks are investigated mainly with regular grids of drill holes.

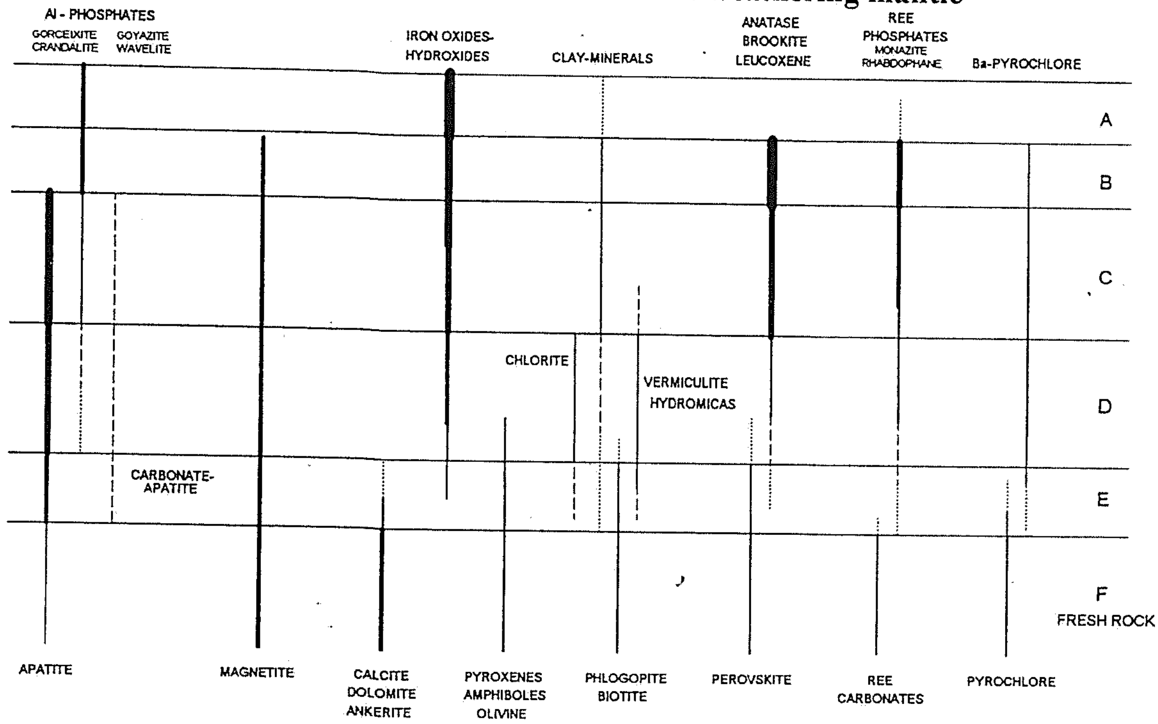
Systematic description of cores, chemical analysis, simple hydrochloric acid tests for carbonates, color and grain size observations will provide sufficient elements to identify the different vertical layers in the weathered material and the main variations of the fresh rocks of the deposit. Each bench is mapped separately, since bench mining is adopted at these deposits. Several different ore types may be macroscopically recognized by grain size and color characteristics, thus being useful even to identify unexpected variations at the mining faces.

Technological efficiency at a concentration plant is expressed by P_2O_5 and mass recovery, concentrate quality and plant throughput. These parameters are influenced by ore characteristics such as slimes content, apatite grain size and degree of liberation, iron oxide coatings on apatite grains, different apatite types and gangue minerals. At several operations even minor proportions of some minerals have shown to be highly deleterious, lowering the overall apatite recovery and/or the concentrate quality. The control of these factors will normally imply in greater reagent consumption or lower production. Thus, ore type characterization and area distribution, to be really useful, must effectively orient mining operations to achieve an adequate ore blending system and allow a good estimation of ore performance at the concentration plant.

Ore type distribution can be adequately monitored by its mineral, geological and chemical characteristics, combined with operational and technological considerations. However, important parameters, such as intensity of iron oxide coatings on apatite grains, can only be established by systematic laboratory determinations on numerous ore samples. This involves times and labor consuming microscopic examinations or heavy liquid separations, associated to Frantz isodynamic magnetic procedures, a technique already routinely adopted at some mines.

The interrelations between mineralogical/geological mapping techniques, ore texture characteristics and analysis of technological factors are intimately associated to industrial performance optimization and to be really effective should be continuously updated and re-examined.

FIGURE 1 - Behavior of the main minerals in the weathering mantle



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